OpenMP ARB, 2007

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OpenMP 3.0

OpenMP ARB

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Tasks

- Adding tasking is the biggest addition for 3.0

- Worked on by a separate subcommittee
  - led by Jay Hoeflinger at Intel

- Re-examined issue from ground up
  - quite different from Intel taskq’s
General task characteristics

- A task has
  - Code to execute
  - A data environment (it owns its data)
  - An assigned thread that executes the code and uses the data

- Two activities: packaging and execution
  - Each encountering thread packages a new instance of a task (code and data)
  - Some thread in the team executes the task at some (potentially later) time
Definitions

- **Task construct** – task directive plus structured block
- **Task** – the package of code and instructions for allocating data created when a thread encounters a task construct
- **Task region** – the dynamic sequence of instructions produced by the execution of a task by a thread
Tasks and OpenMP

- Tasks have been fully integrated into OpenMP
- Key concept: OpenMP has always had tasks, we just never called them that.
  - Thread encountering parallel construct packages up a set of implicit tasks, one per thread.
  - Team of threads is created.
  - Each thread in team is assigned to one of the tasks (and tied to it).
  - Barrier holds original master thread until all implicit tasks are finished.
- We have simply added a way to create a task explicitly for the team to execute.
- Every part of an OpenMP program is part of one task or another!
#pragma omp task [clause[,]clause] ...

structured-block

where clause can be one of:

if (expression)
untied
shared (list)
private (list)
firstprivate (list)
default( shared | none )
The \texttt{if} clause on a \texttt{task} construct

- When the \texttt{if} clause argument is false
  - The current task region is suspended.
  - The new task is executed immediately by the encountering thread.
  - The suspended task region is not resumed until the new task is complete.
  - The data environment is still local to the new task...
  - ...and it’s still a different task with respect to synchronization.

- It’s a user directed optimization
  - when the cost of deferring the task is too great compared to the cost of executing the task code
  - to control cache and memory affinity
When/where are tasks complete?

- At barriers, explicit or implicit
  - applies to all tasks generated in the current parallel region up to the barrier
  - matches user expectation

- At a `taskwait` directive
  - applies only to child tasks of the current task, not to further “descendants”
Example – parallel pointer chasing using tasks

```c
#pragma omp parallel
{
    #pragma omp single private(p)
    {
        p = listhead;
        while (p) {
            #pragma omp task
            process (p)
            p = next (p);
        }
    }
}
```
Example – parallel pointer chasing on multiple lists using tasks

```c
#pragma omp parallel
{
    #pragma omp for private(p)
    for ( int i =0; i <numlists ; i++) {
        p = listheads [ i ] ;
        while (p ) {
            #pragma omp task
            process (p)
            p=next (p ) ;
        }
    }
}
```
Example: tree traversal, children before parents

```c
void traverse(node *p) {
    if (p->left)
        #pragma omp task
        traverse(p->left);
    if (p->right)
        #pragma omp task
        traverse(p->right);
    #pragma omp taskwait
    process(p->data);
}
```

Parent task suspended until child tasks complete
Task switching

- Certain constructs have task scheduling points at defined locations within them.
- When a thread encounters a task scheduling point, it is allowed to suspend the current task and execute another (called task switching).
- It can then return to the original task and resume.
Task switching example

```c
#pragma omp single
{
    for (i=0; i<ONEZILLION; i++)
        #pragma omp task
        process(item[i]);
}
```

- Too many tasks generated in an eye-blink
- Generating task will have to suspend for a while
- With task switching, the executing thread can:
  - execute an already generated task (draining the “task pool”)
  - dive into the encountered task (could be very cache-friendly)
Thread switching

```c
#pragma omp single
{
    #pragma omp task untied
    for (i=0; i<ONEZILLION; i++)
        #pragma omp task
            process(item[i]);
}
```

- Eventually, too many tasks are generated
- Generating task is suspended and executing thread switches to a long and boring task
- Other threads get rid of all already generated tasks, and start starving...

- With thread switching, the generating task can be resumed by a different thread, and starvation is over
- Too strange to be the default: the programmer is responsible!
Performance Results 1

Alignment

FFT

Floorplan

Multisort

All tests run on SGI Altix 4700 with 128 processors
Performance Results 2

All tests run on SGI Altix 4700 with 128 processors
Reference Implementation

- URL: http://mercurium.pc.ac.upc.edu/nanos

- Made by Xavier Teruel, Roger Ferrer, Alex Duran, Eduard Ayguadé, Xavier Martorell
Conclusions on tasks

- Enormous amount of work by many people
- Tightly integrated into 2.5 spec
- Flexible model for irregular parallelism
- Provides balanced solution despite often conflicting goals
- Appears that performance can be reasonable
Better support for nested parallelism

- Per-thread internal control variables
  - Allows, for example, calling `omp_set_num_threads()` inside a parallel region.
  - Controls the team sizes for next level of parallelism
- Library routines to determine depth of nesting, IDs of parent/grandparent etc. threads, team sizes of parent/grandparent etc. teams
  - `omp_get_level()`
  - `omp_get_active_level()`
  - `omp_get_ancestor_thread_num(level)`
  - `omp_get_team_size(level)`

N.B. new defn. of active parallel region: a parallel region executed by more than one thread
Parallel loops

- Guarantee that this works:

```c
!$omp do schedule(static)
do i=1,n
   a(i) = ....
end do
!$omp end do nowait
!$omp do schedule(static)
do i=1,n
   .... = a(i)
end do
```
Loops (cont.)

- Allow collapsing of perfectly nested loops

```c
!$omp parallel do collapse(2)
do i=1,n
    do j=1,n
        ....
    end do
end do
```

- Will form a single loop and then parallelise that
Loops (cont.)

- Made `schedule(runtime)` more useful
  - can get/set it with library routines
    ```
    omp_set_schedule()
    omp_get_schedule()
    ```
  - allow implementations to implement their own schedule kinds
- Added a new schedule kind AUTO which gives full freedom to the runtime to determine the scheduling of iterations to threads.
- Allowed unsigned ints and C++ RandomAccessIterators as loop control variables in parallel loops
Portable control of threads

- Added environment variable to control the size of child threads’ stack
  
  **OMP_STACKSIZE**

- Added environment variable to hint to runtime how to treat idle threads

  **OMP_WAIT_POLICY**
  
  **ACTIVE**  keep threads alive at barriers/locks
  **PASSIVE** try to release processor at barriers/locks
• Added environment variable and runtime routines to get/set the maximum number of active levels of nested parallelism
  
  OMP_MAX_NESTED_LEVELS
  omp_set_max_nested_levels()
  omp_get_max_nested_levels()

• Added environment variable to set maximum number of threads in use
  
  OMP_THREAD_LIMIT
  omp_get_thread_limit()
Odds and ends

- Disallowed use of the original variable as master thread’s private variable
- Made it clearer where/how private objects are constructed/destructed
- Relaxed some restrictions on allocatable arrays
- Plugged some minor gaps in memory model
- Allowed C++ static class members to be threadprivate
- Minor fixes and clarifications to 2.5
Summary

- OpenMP 3.0 is almost ready

- Been a lot of hard work by a lot of people

- We hope you like it: let us know via the public comment process what you think!
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